LA-UR-21-23524
Approved for public release; distribution is unlimited.

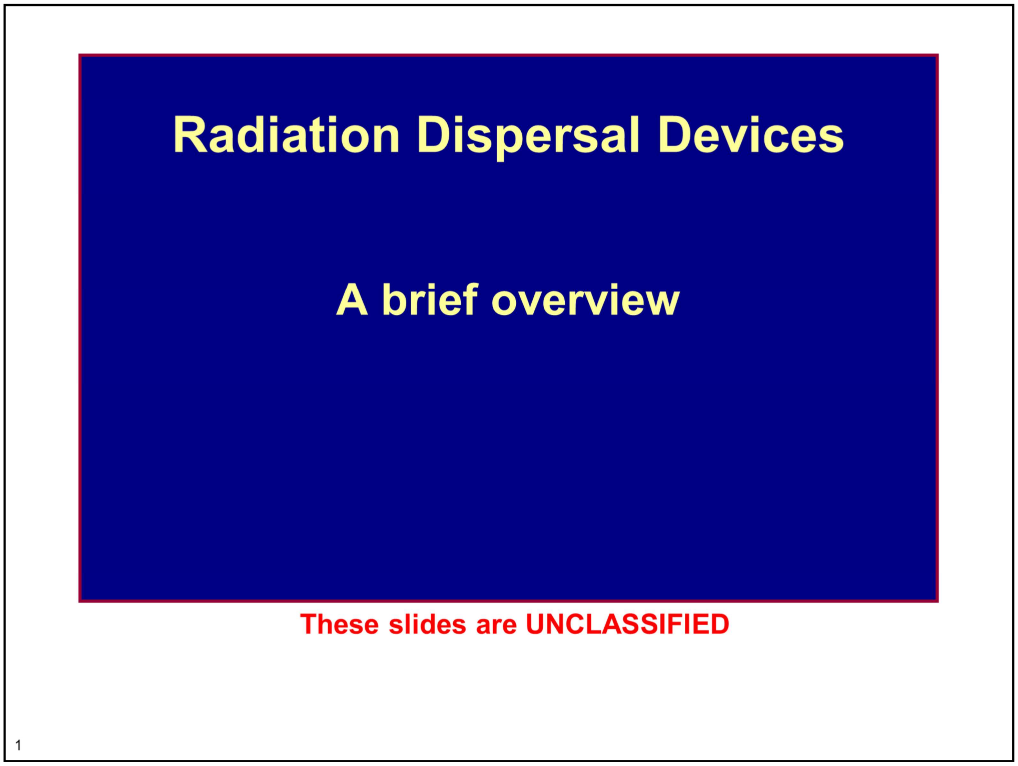
Title: Radiation Dispersal Devices A brief overview

Author(s): Rees, Brian G.

Intended for: Use for classes

Issued: 2021-04-13

Disclaimer:
Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.



In this presentation I lump together the “classical RDD” – a dispersion of aerosolized radioactive material – with the nefarious use of radioactive materials. This can include other means of dispersal as well as an RED – a Radiological Exposure Device. This combination is because the threat is the nefarious use of radioactive material, and most of our concerns are in regards to the loss of control of the material, potential(s) for misuse, and detection.

RDD Class Exercise

- What kind of material
- How much material is needed
  - Physically
- Where obtained
- How long to prepare
- Costs
- Who is needed to prepare
  - Any effects to them
- How will it be used
  - Where
  - How dispersed/deployed
- What will its effects be?

2

Take a few minutes and really think about each of these bullet points. Write down your answers (if unclassified…).

How long did that take you?

Were you able to answer all the questions?

The point here is that coming up with a viable plan really isn't terribly difficult. Yes, some points probably need more work, but in a fairly short period of time a viable plan has been started. And the steps aren't that much more complicated than what you've come up with. It's not like most WMD scenarios where you've got to find adequate supplies, real experts, significant funds, a suitable location, and fairly long time periods (weeks-months). And the result from an RDD is not threshold dependent – if a bio reaction doesn't work or a chemical reaction doesn't occur properly it's a pretty simple clean-up that Hazmat crews are capable of. Radioactive materials will bring attention and cleanup issues significantly greater than any other WMD.

Have There Already Been RDD Attacks?

- **Harassment/Assault – many 10s**
- **Murder – perhaps 10**
- **Untargeted (but minor) – around 5**

3

There have been nefarious uses of radioactive material, published accounts surface every few years. Most of these accounts are targeted against one person, or possibly a small group of people, and involve the use of materials that are opportunistically available to the attacker due to their work. Very few of these attacks result in physical damage to the victims.

There have been reports of radioactive materials used to murder people, probably the most notable is the case of Alexander Litvinenko, a former FSB officer that was poisoned by Russian agents. Other murder cases are reported to have been conducted by Russian mafia.

There are very few reported cases of radioactive material being used to contaminate areas without a known, identified target person or group.

Bio. vs. Chem. vs Rad.

Anthrax	Sarin	Cesium-137
Fall 2001 US East Coast	3/20/95 Tokyo Subway	9/13/87 Goiania, Brazil
5 letters ~2 grams/envelope 2×10^{12} spores/envelope	~7 kg total ~4.5 kg released	1375 Ci 16 grams
2×10^{8} Lethal Doses	**4×10^{6} Lethal Doses**	**10^{5} Lethal Doses**
5 deaths ~24 ill ~10^{4} rec'd antibiotics	10 deaths ~37 moderately ill 5510 sought care	4 deaths 20 hospitalized 112,000 monitored

4

Discussions of radioactive material misuse should include other WMD materials. All three of these are real-world events, and while the Cs-137 event in Goiania was not an intentional misuse, it is the closest we have to an intentional dispersal.

Probably the most notable point here is that for all of these events there are enormous potential fatalities, yet the death toll for all of them is very small in comparison to the potential. This is in large part because to cause harm, an ingested or inhaled material must be delivered to the right organ, in the right physical form, in the right chemical form, to the right pathway. If any of these steps are defective or absent the potential harm from a material is greatly reduced or eliminated.

A great example of this is Sr-90. An intake of Sr-90 has the potential for significant dose because it is a calcium analog, and can be absorbed onto bone and incorporated into the bone. The half-life is fairly short (29 years), and the beta it gives off can damage bone marrow – which forms red blood cells. Some Radioisotopic Thermal Generators (RTGs) use 100's of thousands of Curies of Sr-90, but the Sr-90 is bonded to Titanium to make SrTiO3 – a material that is inert to the body and unneeded by the body – so it is excreted and not retained – resulting in minimal radiation dose.

Anthropogenic Radiation Sources

5

Naturally Occurring Radioactive Materials that have not been separated or concentrated are not considered hazardous in most circumstances or very useful for nefarious purposes. Fabricated sources do have that potential.

Radiographic and Other Industrial Sources

- **Cobalt-60 – gamma; metal**
- **Cesium-137 – gamma; soluble compound, ceramic**
- **Iridium-192 – gamma; metal**
- **Radium (Radon) – gamma; soluble compound**
- **Strontium-90/Yttrium-90 – beta; insoluble or soluble compound**

6

These are a few of the more commonly discussed radioactive sources and some pertinent general information about them:

Co-60 is a metal, so it must be processed to be dispersible. It has a 5 year half-life and two high-energy gamma rays at 1332 and 1173 keV. In its use for industrial radiography it's transported in large (suitcase-size) depleted uranium transport containers weighing hundreds of pounds. Co-60 is usually created by irradiating Co-59 with neutrons in a reactor.

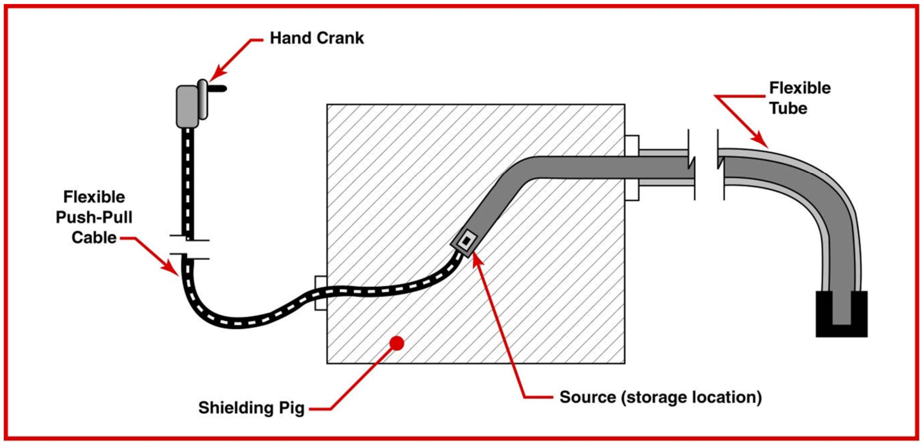
Cs-137 is commonly used as a salt – CsCl – and is highly water soluble. It has a 30 year half life and a moderate-energy gamma ray at 662 keV. This gamma ray is convenient for industrial thickness and level gages because it is high enough energy to have good penetration, while having a low enough energy to be easily shielded and having a good probability of interaction in a radiation detector. Its half life is long enough to not require frequent source replacement or equipment recalibration. Many smuggling and loss-of-control cases involve Cs-137 because of its popularity in industrial processes. Cs-137 is a common fission product, and is extracted during nuclear fuel reprocessing.

Ir-192 is a metal, and very difficult to dissolve with most acids. It has a 74 day half life, and a variety of low-moderate energy gamma rays (316, 468, 308, 296, and more) which make it ideal for creating high-resolution radiographs in the field. It is transported in a lunchbox-sized depleted uranium shield weighing approximately 30-50 pounds. It is usually created by irradiating Ir-191 in a nuclear reactor.

Ra-226 is usually found as a salt – $RaCl_2$ – and is water soluble. It has a 1600 year half life, and while it's primarily an alpha-emitter, its numerous progeny emit quite a few gamma rays, which are responsible for the external dose. Ra-226 was popular in the first half of the 20th century as a brachytherapy source and for reputed health benefits, but is not commonly used now. It is a bone-seeker and is incorporated into bone, delivering considerable radiation dose to the bone surface and marrow. It is separated from uranium ore or compounds.

Sr-90 is usually found as a salt, but can be part of other compounds. It has a 29 year half life and has a high-energy beta. Its progeny, Y-90 has a few low-abundance gamma rays. Sr-90 is used for its beta emissions in some industrial, military, and medical uses as well as a heat source for RTGs (discussed previously). Sr-90 is a common fission product and is separated from nuclear fuels.

Schematic of a Typical Source Storage/Deployment Arrangement



This is a schematic of a radiography source pig or “camera” with the source stowed. When the source is stowed there is no direct path for gamma rays out to the environment. To use the source, the end of a flexible tube is led to where a radiograph is to be taken, and an operating cable is connected to the source. The source is pushed out of the camera to the end of the flexible tube, where it exposes film placed on the other side of the object to be irradiated. After the exposure is completed the source is withdrawn back to the camera and the tube and cable are disconnected. The camera is lunchbox-sized, frequently constructed of depleted uranium, and has can emit single-scatter gamma rays with energy proportional to the angle of scatter.

Industrial Irradiator

Curie Content and Exposure Tunnel

IRRADIATOR	CURIE CONTENT	MAX. DOSE RATE	MIN. DOSE RATE
High Dose	19,200 Co_{60}	10^7 R/Hr 145 krad(SiO_2)/min	200 R/Hr 2.9 rad(SiO_2)/min
Low Dose	100 Co_{60}	$6x10^3$ R/Hr 87 rad(SiO_2)/min	100 R/Hr 1.45 rad(SiO_2)/min
Low Dose	130 Cs_{137}	$6x10^3$ R/Hr 87 rad(SiO_2)/min	100 R/Hr 1.45 rad(SiO_2)/min

Cesium and Cobalt irradiators are used in a variety of industrial and research applications, primarily for sterilization. Typically, these units can contain significant quantities of radioisotopes in a sealed source form.

This is an example of an industrial irradiator used for research inot.

Portable Nuclear Gages

Moisture/density gages used in construction are one of the most common nuclear sealed source applications. Tens of thousands of such units have been distributed world wide. Typically each gage contains one 10-20 mCi Cesium source and one 40-100 mCi Americium/Beryllium neutron source.

9

These soil moisture density gages are commonly used in the construction industry to measure soil compaction, particularly for large commercial and industrial buildings. Poor compaction results in cracked foundations, and when compaction is completed, the work can proceed. The soil tester frequently drives one of the nicest vehicles on site, which makes them thievery targets. These gages are frequently stolen with the truck, and usually recovered fairly quickly. Since the boxes they are stored in are well-secured to the truck, that also helps to make them attractive to thieves.

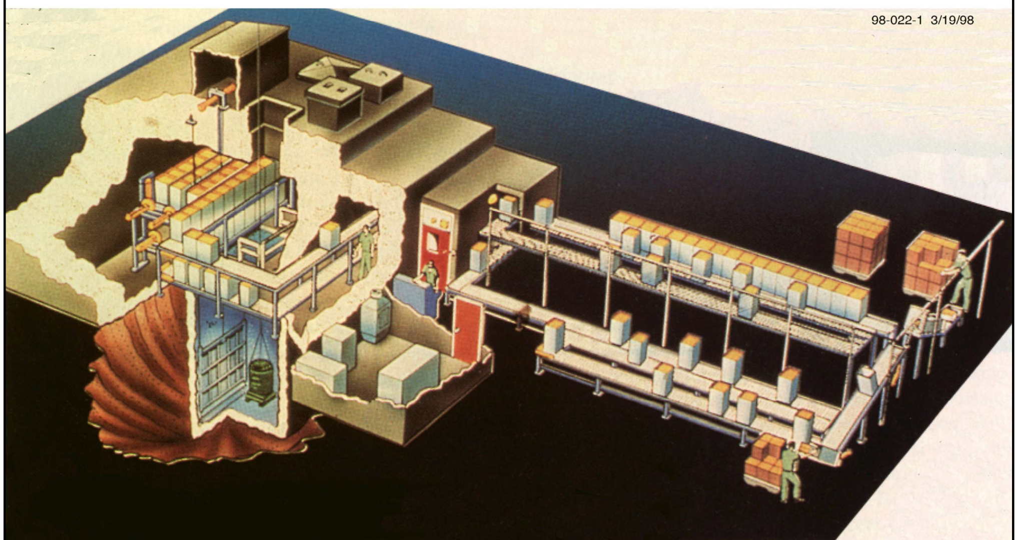
Blood Irradiators

Irradiation of blood & blood products by gamma rays is a proven and safe method to inhibit T-Lymphocyte Proliferation and eliminate the risk of post transfusion graft versus host disease (T-GVHD). Blood is usually irradiated in standard blood bags in dedicated blood irradiators using Cobalt-60 or Cesium-137 radioactive source. Typically blood irradiators use a number of individual sources containing around 100 Curies each of Cesium or Cobalt. The usual recommended radiation doses are 25 Gy to 35 Gy (1 Gy = 100 rad) for this purposes.

Blood irradiators are in some larger regional hospitals. There is one blood irradiator for approximately 250,000-500,000 population.

Radiosterilization Facility

MCi of Co-60 or Cs-137



11

Many medical products are sterilized with radiation because you can seal the package and have great confidence all pathogens have been killed, and that the device will remain sterile while in its package. Some foods are also sterilized with radiation. Radiosterilization facilities use MCi quantities of radioactive material, frequently Co-60 due to its high gamma ray energy and insolubility. The sources are placed in racks, and frequently stored in a water-filled pool for shielding, cooling, and ease of manipulation. The sources must be rotated within the racks to ensure irradiation uniformity. Sources are also exchanged with fresh sources from time-to-time due to the short half life of Co-60. The multi-ton transport casks are highly effective in shielding the 1173 keV gamma ray, but some 1332 keV gamma rays may be observable.

Radioisotopic Thermoelectric Generators (RTG)

- **Applications: Remote Power**
  - **Internal, Space, Deep Oceans, Terrestrial**
  - **For example: pacemakers, remote Russian lighthouses, remote Alaskan seismometers**
- **Sr-90 (β-emitter) & Pu-238 (α-emitter) used**
  - **Sr-90: $t_{1/2}$ = 28.8 yr, strong bone seeker (Y-90)**
  - **Pu-238: $t_{1/2}$ = 87.7 yr, serious inhalation hazard**

- **Russian Sr-90 RTGs: 50 kCi (1,850 TBq) - 18 We**
  260 kCi (9,620 TBq) - 130 We

- **U.S. Sr-90 RTGs: 107 kCi (3,960 TBq) - 31 We**
  328 kCi (12,136 TBq) - 98 We

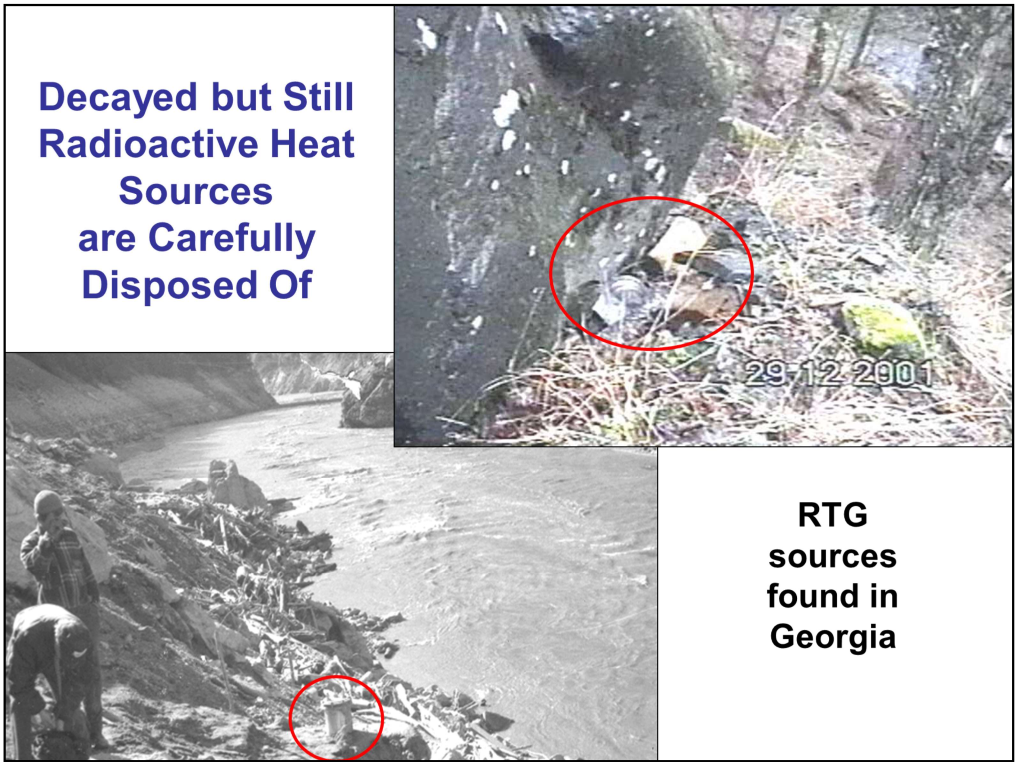
12

RTGs are used to convert heat from radioisotopes directly to electricity in remote or difficult to access areas. Pu-238 RTGs were used in some of the first cardiac pacemakers, but most of them are no longer in use. Due to the higher specific heat output, Pu-238 is more common use in outer space. Sr-90 is more common in terrestrial applications.

Russian Sr-90 RTGs

13

Photo showing Russian Sr-90 RTGs. These may contain kCi's (kgs) of Sr-90



https://www.nti.org/analysis/articles/radiothermal-generators-containing-strontium-90-discovered-liya-georgia/

The IAEA report in PDF is available for download at https://www.iaea.org/publications/10602/the-radiological-accident-in-lia-Georgia

Irradiated (Spent) Reactor Fuel

- **Enormous Range of Materials/Configurations**
  - **Huge (4 m, 660 kg) sintered LEU oxide clad w/ Zirconium alloy**
  - **Handy (0.6 m, 0.3 kg) HEU alloy clad w/ Aluminum**
  - **Everything in between**

- **Enormous Range of Radioactivity, from Fresh to:**
  - **At-discharge LWR = $9\text{x}10^8$ Rem/hr**
  - **5y Since-discharge LWR = $1.6\text{x}10^3$ Rem/hr**
  - **20y Since-discharge LWR = 100 Rem/hr**

15

Some spent fuel bundles are too large to consider for nefarious use, but others are feasible.

Weird Science

Electronic neutron generators, or high-power x-ray devices are available commercially. They’re not cheap or common, but can’t be ruled out.

Malevolent Use

17

There are many considerations to using radioactive sources malevolently.

Source Dispersal Techniques

- **Explosives**
- **Fire**
- **Aerodynamic**
- **Solution**
- **Passive**

There are a variety of techniques that could be used to disperse materials.

Explosive Dispersal

- **Results uncertain**
  - **HE – Source coupling**
  - **Surrounding material**
- **Dispersal reduces hazard**
- **Detonations draw attention**
- **Easy**

Explosive dispersal is the most commonly discussed method of dispersal for an RDD. But it’s not as simple as it sounds, and has some serious drawbacks for effectiveness.

00S-022-20 4/00

Effect of Dispersal

(adapted from LLNL study)

Fixed Placement Example:

A bare 10 Ci Cobalt-60 source in a fixed location gives a dose of about 150 rem/hr to people one foot away.

Walking by slowly gives a dose of about 85 mrem.

Dispersed Placement Example:

10 Ci of Cobalt-60 spread uniformly over one square kilometer would give people in this area a dose of about 0.4 mrem/hr.

Walking through gives a dose of approx. 0.06 mrem

20

Dispersal may not be the optimum use of the material. In this example, the dose received from a dispersed source is easily contextualized to members of the public, and clearly trivial. The dose from a non-dispersed source is difficult to explain as trivial.

Passive (non-) Dispersal

- Maximizes hazard
- Can minimize response
- Targets a specific group

Not creating an airborne dispersal is an option too.

Psychological Scenario

- **Minimal threat, public fear high**
- **Response driven by public perceptions and fears, not science**
- **Rogue rad measurements and/or interpretations may exacerbate concern**
- **Threats are common, must overcome the publication barrier**

Fake news might work too.

Large Sources Bring Operational Problems

- Personnel Hazard
  - Disability in few minutes to hours
- Detectability
- Heat
- Damage to Electronics
- OPSEC

Inexperienced people and large sources don't mix well. There are numerous aspects to large sources that may not be anticipated or appreciated.

Jihadist Website Posting

FBIS 10/1/03 from 9/30/03 posting

- **Sada al-Jihad**
  - **897 members, strong Kurdish Islamist interest**
  - **<Mansoor123>**
- **High cost of cleanup**
- **Become involved in transportation to obtain**
- **Use Cs-137 or radiopharmaceuticals**
- **Examples of accidents and disruption**

This posting has been seen again and again. The author of the posting did some research, and urged people to pursue RDD use.